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Ionization Potentials and Ionization Limits Derived From the Analyses of Optical Spectra

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U. S. NATIONAL BUREAU OF STANDARDS • LEWIS M. BRANSCOMB, *Director*

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Charlotte E. Moore

Office of Standard Reference Data
National Bureau of Standards
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FOREWORD

The National Standard Reference Data System provides effective access to the quantitative data of physical science, critically evaluated and compiled for convenience, and readily accessible through a variety of distribution channels. The System was established in 1963 by action of the President's Office of Science and Technology and the Federal Council for Science and Technology, with responsibility to administer it assigned to the National Bureau of Standards.

The System now comprises a complex of data centers and other activities, carried on in academic institutions and other laboratories both in and out of government. The independent operational status of existing critical data projects is maintained and encouraged. Data centers that are components of the NSRDS produce compilations of critically evaluated data, critical reviews of the state of quantitative knowledge in specialized areas, and computations of useful functions derived from standard reference data. In addition, the centers and projects establish criteria for evaluation and compilation of data and make recommendations on needed improvements in experimental techniques. They are normally closely associated with active research in the relevant field.

The technical scope of the NSRDS is indicated by the principal categories of data compilation projects now active or being planned: nuclear properties, atomic and molecular properties, solid state properties, thermodynamic and transport properties, chemical kinetics, and colloid and surface properties.

The NSRDS receives advice and planning assistance from the National Research Council of the National Academy of Sciences-National Academy of Engineering. An overall Review Committee considers the program as a whole and makes recommendations on policy, long-term planning, and international collaboration. Advisory Panels, each concerned with a single technical area, meet regularly to examine major portions of the program, assign relative priorities, and identify specific key problems in need of further attention. For selected specific topics, the Advisory Panels sponsor subpanels which make detailed studies of users' needs, the present state of knowledge, and existing data resources as a basis for recommending one or more data compilation activities. This assembly of advisory services contributes greatly to the guidance of NSRDS activities.

The NSRDS–NBS series of publications is intended primarily to include evaluated reference data and critical reviews of long-term interest to the scientific and technical community.

LEWIS M. BRANSCOMB, *Director*

Contents

Ionization Potentials and Ionization Limits Derived from the Analyses of Optical Spectra

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A current table of ionization potentials expressed in electron volts and a detailed table giving the limits from which they have been derived are presented. For each spectrum the ground term is given, with the limit as the ground state. The energy levels of terms of the lowest configuration determined from ground state zero, are also included for selected spectra. The literature references used for each spectrum are indicated by number and listed in a bibliography with some 200 entries.

The latest recommended conversion factor (cm^{-1} to eV) 0.000123981 corresponding to 1 eV = 8065.73 cm^{-1} has been used throughout.

Key words: Atomic spectra, ground terms; ground terms, atomic spectra; ionization limits; ionization potentials.

The data in the Volumes on "Atomic Energy Levels" (AEL) [135], [136], [137], include the ionization limits known for individual spectra. The latest table of ionization potentials calculated from these limits was published as Table 34 in Volume III (1958). Much work has been done since then and there has been a steady demand for a revision of this Table.

A fairly comprehensive general bibliography has recently been published [194] which lists for each spectrum the literature references on analyses of atomic spectra dating from the entries in the respective Volume of "AEL" (1949), (1952), (1958), well into 1968. The present compendium is based largely on the references in this Bibliography, with some, but probably not all, later material.

The reliability of the data recorded in the literature is often difficult to appraise. In cases where long series are known in the various spectra, the ionization potentials are well determined. With these as key points, good values can be derived by extrapolation or interpolation along isoelectronic sequences, or by comparison along the rows in the Periodic Chart for spectra of similar stages of ionization. Frequently, however, authors give values of ionization potentials without stating the conversion factor used and without describing clearly how the quoted value was obtained.

For this reason, the present paper includes not only the ionization potentials in eV, but also, the limits in cm^{-1} from which these have been derived. Table 1 gives the ionization potentials in eV for each spectrum.

The conversion factor taken from [195] was used for Table 1, since it is the value currently recommended by the National Academy of Sciences-National Research Council. However, recent measurements [200] suggest that this value may be in error by about 30 parts per million. Therefore, it should be understood that all of the significant figures included in Table 1 may not be meaningful in an absolute sense. This applies particularly to entries with magnitudes greater than 100 eV.

All limits have been multiplied by the factor 0.000123981 to obtain the entries in Table 1, i.e., 1 eV = 8065.73 cm^{-1}. The factor used in "AEL" was 0.00012395 and has been superseded. As a result, in the present table there are systematic differences from the 1958 Table, caused by the change in the conversion factor, as well as the differences caused by improved values of the limits.

Italics denote ionization potentials derived from limits that are bracketed in Table 2.

In compiling Table 1 the author has attempted to indicate roughly the various degrees of accuracy of the limits. Those based on well-established series deserve the greatest weight. When the ionization potential is given to three places, it is felt that the third place is meaningful. The two- and one-place entries are less well defined, but it is hoped that they have some significance. The limits of error assigned by the various investigators provide a general criterion, but these are given for comparatively few spectra. Users should, therefore, consult the limits given in Table 2 and the references in order to evaluate the data for individual spectra.

Table 2 contains the basic data for each spectrum. As in Table 1, the successive stages of ionization are indicated at the heading of each column: I, denoting first spectra (neutral atoms); II, second spectra (singly ionized atoms), etc. The elements are arranged in order of increasing atomic number, Z. The ground state is indicated for each spectrum, together with the ionization limit in cm^{-1}. In every case this limit refers to the ground state of the ion in the next higher stage of ionization. The limits of error are quoted from the original authors. Although not specifically defined, these afford a general guide as to the reliability of the limit.

Although all limits are based on data derived from the analyses of optical spectra, they are determined in various ways, since reliable series are

TABLE I. *Ionization potentials**

Z	Element	Spectrum									
		I	II	III	IV	V	VI	VII	VIII	IX	X
1	H	13.598									
2	He	24.587	54.416								
3	Li	5.392	75.638	122.451							
4	Be	9.322	18.211	153.893	217.713						
5	B	8.298	25.154	37.930	259.368	340.217					
6	C	11.260	24.383	47.887	64.492	392.077	489.981				
7	N	14.534	29.601	47.448	77.472	97.888	552.057	667.029			
8	O	13.618	35.116	54.934	77.412	113.896	138.116	739.315	871.387		
9	F	17.422	34.970	62.707	87.138	114.240	157.161	185.182	953.886	1103.089	
10	Ne	21.564	40.962	63.45	97.11	126.21	157.93	207.27	239.09	1195.797	1362.164
11	Na	5.139	47.286	71.64	98.91	138.39	172.15	208.47	264.18	299.87	1465.091
12	Mg	7.646	15.035	80.143	109.24	141.26	186.50	224.94	265.90	327.95	367.53
13	Al	5.986	18.828	28.447	119.99	153.71	190.47	241.43	284.59	330.21	398.57
14	Si	8.151	16.345	33.492	45.141	166.77	205.05	246.52	303.17	351.10	401.43
15	P	10.486	19.725	30.18	51.37	65.023	220.43	263.22	309.41	371.73	424.50
16	S	10.360	23.33	34.83	47.30	*72.68*	88.049	280.93	328.23	379.10	447.09
17	Cl	12.967	23.81	39.61	53.46	67.8	*97.03*	114.193	348.28	400.05	455.62
18	Ar	15.759	27.629	40.74	59.81	75.02	91.007	124.319	143.456	422.44	478.68
19	K	4.341	31.625	45.72	60.91	*82.66*	*100.0*	117.56	154.86	175.814	503.44
20	Ca	6.113	11.871	50.908	67.10	84.41	*108.78*	127.7	147.24	188.54	211.270
21	Sc	6.54	12.80	24.76	73.47	91.66	111.1	*138.0*	158.7	180.02	225.32
22	Ti	6.82	13.58	27.491	43.266	99.22	119.36	140.8	168.5	*193.2*	215.91
23	V	6.74	14.65	29.310	46.707	*65.23*	128.12	150.17	173.7	*205.8*	*230.5*
24	Cr	6.766	16.50	30.96	*49.1*	*69.3*	90.56	161.1	*184.7*	*209.3*	*244.4*
25	Mn	7.435	15.640	33.667	*51.2*	*72.4*	*95*	119.27	*196.46*	*221.8*	*243.3*
26	Fe	7.870	16.18	30.651	*54.8*	*75.0*	*99*	*125*	151.06	235.04	262.1
27	Co	7.86	17.06	33.50	*51.3*	*79.5*	*102*	*129*	*157*	186.13	276
28	Ni	7.635	18.168	35.17	*54.9*	*75.5*	*108*	*133*	*162*	*193*	224.5
29	Cu	7.726	20.292	36.83	55.2	*79.9*	*103*	*139*	*166*	*199*	*232*
30	Zn	9.394	17.964	39.722	*59.4*	*82.6*	*108*	*134*	*174*	*203*	*238*
31	Ga	5.999	20.51	30.71	64						
32	Ge	7.899	15.934	34.22	45.71	93.5					
33	As	9.81	18.633	28.351	50.13	62.63	127.6				
34	Se	9.752	21.19	30.820	42.944	*68.3*	81.70	155.4			
35	Br	11.814	21.8	36	*47.3*	*59.7*	*88.6*	*103.0*	192.8		
36	Kr	13.999	24.359	36.95	*52.5*	*64.7*	*78.5*	*111.0*	*126*	230.9	
37	Rb	4.177	27.28	40	*52.6*	*71.0*	*84.4*	*99.2*	*136*	*150*	277.1
38	Sr	5.695	11.030	*43.6*	57	*71.6*	*90.8*	*106*	*122.3*	*162*	*177*
39	Y	6.38	12.24	20.52	*61.8*	*77.0*	*93.0*	*116*	*129*	*146.2*	*191*
40	Zr	6.84	13.13	22.99	34.34	81.5					
41	Nb	6.88	14.32	25.04	38.3	50.55	102.6	125			
42	Mo	7.099	16.15	27.16	46.4	61.2	68	126.8	153		

TABLE I. *Ionization potentials** — Continued

Spectrum — Continued											Z
XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	
											1
											2
											3
											4
											5
											6
											7
											8
											9
											10
1648.659											11
1761.802	1962.613										12
442.07	2085.983	2304.080									13
476.06	523.50	2437.676	2673.108								14
479.57	560.41	611.85	2816.943	3069.762							15
504.78	564.65	651.63	707.14	3223.836	3494.099						16
529.26	591.97	656.69	749.74	809.39	3658.425	3946.193					17
538.95	618.24	686.09	755.73	854.75	*918*	4120.778	4426.114				18
564.13	629.09	714.02	787.13	861.77	*968*	*1034*	4610.955	4933.931			19
591.25	656.39	726.03	816.61	895.12	*974*	*1087*	*1157*	5129.045	5469.738		20
249.832	685.89	755.47	829.79	926.00							21
265.23	291.497	787.33	861.33	940.36							22
255.04	308.25	336.267	895.58	974.02							23
270.8	*298.0*	355	384.30	1010.64							24
286.0	*314.4*	*343.6*	404	435.3	1136.2						25
290.4	*330.8*	*361.0*	*392.2*	457	489.5	1266.1					26
305	*336*	*379*	*411*	*444*	512	546.8	1403.0				27
321.2	*352*	*384*	*430*	*464*	*499*	*571*	607.2	1547			28
266	*368.8*	*401*	*435*	*484*	*520*	*557*	*633*	671	1698		29
274	*310.8*	*419.7*	*454*	*490*	*542*	*579*	*619*	*698*	738	1856	30
											31
											32
											33
											34
											35
											36
											37
324.1											38
206	374.0										39
											40
											41
											42

TABLE I. *Ionization potentials** – Continued

Z	Element	Spectrum I	II	III	IV	V	VI	VII	VIII	IX	X
43	Tc	7.28	15.26	29.54							
44	Ru	7.37	16.76	28.47							
45	Rh	7.46	18.08	31.06							
46	Pd	8.34	19.43	32.93							
47	Ag	7.576	21.49	34.83							
48	Cd	8.993	16.908	37.48							
49	In	5.786	18.869	28.03	54						
50	Sn	7.344	14.632	30.502	40.734	72.28					
51	Sb	8.641	16.53	25.3	44.2	56	108				
52	Te	9.009	18.6	27.96	37.41	58.75	70.7	137			
53	I	10.451	19.131	*33*							
54	Xe	12.130	21.21	32.1							
55	Cs	3.894	25.1								
56	Ba	5.212	10.004								
57	La	5.577	11.06	19.175							
58	Ce	5.47	10.85	20.20	36.72						
59	Pr	5.42	10.55	21.62	38.95	57.45					
60	Nd	5.49	10.72								
61	Pm	5.55	10.90								
62	Sm	5.63	11.07								
63	Eu	5.67	11.25								
64	Gd	6.14	12.1								
65	Tb	5.85	11.52								
66	Dy	5.93	11.67								
67	Ho	6.02	11.80								
68	Er	6.10	11.93								
69	Tm	6.18	12.05	23.71							
70	Yb	6.254	12.17	25.2							
71	Lu	5.426	13.9								
72	Hf	7.0	14.9	23.3	33.3						
73	Ta	7.89									
74	W	7.98									
75	Re	7.88									
76	Os	8.7									
77	Ir	9.1									
78	Pt	9.0	18.563								
79	Au	9.225	20.5								
80	Hg	10.437	18.756	34.2							
81	Tl	6.108	20.428	29.83							
82	Pb	7.416	15.032	31.937	42.32	68.8					
83	Bi	7.289	16.69	25.56	45.3	56.0	88.3				

TABLE I. *Ionization potentials** – Continued

Z	Element	Spectrum I	II	III	IV	V
84	Po	8.42				
·86	At					
86	Rn	10.748				
87	Fr					
88	Ra	5.279	10.147			
89	Ac	6.9	12.1			
90	Th		11.5	20.0	28.8	
91	Pa					
92	U					
93	Np					
94	Pu	5.8				
95	Am	6.0				

*$1\,cm^{-1} = 0.000123981$ eV.

known for only a limited number of spectra. For the H I and He I isoelectronic sequences, the theoretical values quoted here are well determined. Edlén, [44], [45], [46], [47], has made a detailed study of formulae for extrapolating ionization limits along sequences of the lighter elements. His values are extensively quoted in Table 2.

Catalán and his associates, [22 to 27], have interpolated values for spectra of neighboring elements in the same stage of ionization. These have been used for spectra in which series are not known. Russell, [166], Sugar and Reader, [156], [181] and others, have described similar general relationships between spectra, that can be used to derive fairly reliable limits.

In Table 2 all ionization limits were recorded that were derived from observed series, from extrapolation or interpolation as described above (Edlén, Catalán, etc.), or from theoretical calculations such as those of the H I and He I series. When all available data from these sources had been entered, if gaps still remained for spectra of a given element in successive stages of ionization, the intervening limits were entered in brackets, as for Ti VIII and Ti IX. These limits, in brackets, represent calculated values interpolated or extrapolated from observed data, and reported in two general tables of ionization potentials in which different methods have been used. For scattered spectra of the elements S V through Zn XIX, the table of Lotz, [116], has been quoted. For larger atomic numbers, the entries in brackets are from the table of Finkelnburg and Humbach, [65]. No attempt has been made, however, to quote *all* such calculated values.

The need for higher ionization limits within a given spectrum increases as laboratory research on absorption series in the vacuum ultraviolet, on series produced with synchrotron radiation as a source, and the like, advances. At the request of workers in these fields, all components of the ground term, and in selected cases, all levels from the ground configuration, are entered in Table 2. All levels above the ground state are relative to the ground state zero. For example, in the format of "AEL," the lowest levels of O I are as follows:

Desig.	AEL	Table 2
$2p^4\,{}^3P_2$	0.000	109837.02 = Limit
${}^3P_1$	158.265	158.265
${}^3P_0$	226.977	226.977
${}^1D_2$	15867.862	15867.862
${}^1S_0$	33792.583	33792.583

In compiling Table 2, the energy levels of *only* the ground term have been included for complex spectra, particularly with increasing *Z*. It is well known that in rare-earth spectra low configurations and low terms overlap in many cases. Consequently, many more low energy levels may be known than those of the ground term. Users are urged to recognize this limitation of the Table and to consult the literature references for further details concerning the low levels that have been reported for individual spectra.

As in "AEL" estimated values of energy levels are given in brackets. Similarly, "*x*" denotes that the energy level is not connected by observation with the others.

In Table 2, under the term designations for each spectrum, the numbers in italics at the lower left, refer to Table 3. This table is a Bibliography which contains the literature references used for each spectrum to obtain the limits and terms quoted in Table 2.

The importance of stating, clearly, how a limit or an ionization potential has been derived cannot be overemphasized. It is hoped that the present tables will enable each user to judge the quality of the available data used to compile Table 1.

Although the foregoing results are limited to optical spectra, it should be recognized that experimental values of ionization energies have, also, been published. A surface ionization method has been used to obtain ionization potentials for first spectra of rare earths, [196 to 198]. In general, the agreement is satisfactory between the values obtained by the different methods.

Estimates of ionization potentials of third spectra of the lanthanons have been calculated recently "by applying the Born-Haber cycle to the group 3A oxides and arsenides." [199].

After the work on the present publication had been started, the author learned that extensive revisions of the data on the spectra of lighter elements were being prepared by B. Edlén, J. O. Ekberg, and L. Å. Svensson, in Lund. They have most generously furnished much valuable material, in advance of publication, for inclusion here. The author is deeply indebted to these colleagues whose expert judgment and advice greatly enhance the value of the present publication. She is equally grateful to all others who have so willingly contributed their unpublished material.

Washington, D.C.
April 22, 1970

Table 3. Bibliography

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TABLE 2. *Ionization limits and lowest terms*

Z	Element	Spectrum I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	H	$1s$ $^2S_{0\frac{1}{2}}$ 109678.764 *68*											
2	He	$1s^2$ $^1S_0$ 198310.76 ±0.01 *119, 169a*	$1s$ $^2S_{0\frac{1}{2}}$ 438908.85 *68*										
3	Li	$2s$ $^2S_{0\frac{1}{2}}$ 43487.150 ±0.005 *90*	$1s^2$ $^1S_0$ 610079.0 ±0.1 *49, 81, 145*	$1s$ $^2S_{0\frac{1}{2}}$ 987660.1 *49, 68*									
4	Be	$2s^2$ $^1S_0$ 75192.07 *93*	$2s$ $^2S_{0\frac{1}{2}}$ 146882.86 *92*	$1s^2$ $^1S_0$ 1241259.4 *145*	$1s$ $^2S_{0\frac{1}{2}}$ 1756018.7 68								
5	B	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 66928.10 ±0.1 $^2P^\circ_{1\frac{1}{2}}$ 15.254 *48, 142*	$2s^2$ $^1S_0$ 202887.4 ±0.8 *141*	$2s$ $^2S_{0\frac{1}{2}}$ 305931.1 ±0.6 *140*	$1s^2$ $^1S_0$ 2092001.4 *49, 145*	$1s$ $^2S_{0\frac{1}{2}}$ 2744105.1 *49, 68*							
6	C	$2p^2$ $^3P_0$ 90820.42 ±0.1 $^3P_1$ 16.40 $^3P_2$ 43.40 $^1D_2$ 10192.63 $^1S_0$ 21648.01 *94*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 196664.7 $^2P^\circ_{1\frac{1}{2}}$ 63.42 *18, 48*	$2s^2$ $^1S_0$ 386241.0 ±2 *13, 141*	$2s$ $^2S_{0\frac{1}{2}}$ 520178.4 ±1.5 *9, 49, 140*	$1s^2$ $^1S_0$ 3162395 *49* ±30	$1s$ $^2S_{0\frac{1}{2}}$ 3952061.4 *49, 68*						
7	N	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 117225.4 $^2D^\circ_{2\frac{1}{2}}$ 19224.464 $^2D^\circ_{1\frac{1}{2}}$ 19233.177 $^2P^\circ_{0\frac{1}{2}}$ 28838.920 $^2P^\circ_{1\frac{1}{2}}$ 28839.306 *55, 123*	$2p^2$ $^3P_0$ 238750.5 ±1.3 $^3P_1$ 48.7 $^3P_2$ 130.8 $^1D_2$ 15316.2 $^1S_0$ 32688.8 *53*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 382704 $^2P^\circ_{1\frac{1}{2}}$ 174.36 *48, 53, 78*	$2s^2$ $^1S_0$ 624866 ±3 *77, 141*	$2s$ $^2S_{0\frac{1}{2}}$ 789537.2 ±3.0 76	$1s^2$ $^1S_0$ 4452758 *49, 145*	$1s$ $^2S_{0\frac{1}{2}}$ 5380089 68					
8	O	$2p^4$ $^3P_2$ 109837.02 ±0.06 $^3P_1$ 158.265 $^3P_0$ 226.977 $^1D_2$ 15867.862 $^1S_0$ 33792.583 *17, 54, 57*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 283240 $^2D^\circ_{2\frac{1}{2}}$ 26810.7 $^2D^\circ_{1\frac{1}{2}}$ 26830.5 $^2P^\circ_{1\frac{1}{2}}$ 40466.9 $^2P^\circ_{0\frac{1}{2}}$ 40468.4 *17, 46, 135*	$2p^2$ $^3P_0$ 443086 $^3P_1$ 113.9 $^3P_2$ 306.9 $^1D_2$ 20274 $^1S_0$ 43186 *10, 17*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 624383.8 ±2.0 $^2P^\circ_{1\frac{1}{2}}$ 385.9 *19, 48*	$2s^2$ $^1S_0$ 918657 ±4 *15*	$2s$ $^2S_{0\frac{1}{2}}$ 1114008 *14, 49* ±10	$1s^2$ $^1S_0$ 5963135 *145*	$1s$ $^2S_{0\frac{1}{2}}$ 7028393 *68*				
9	F	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 140524.5 ±0.4 $^2P^\circ_{0\frac{1}{2}}$ 404.1 *48, 115*	$2p^4$ $^3P_2$ 282058.6 ±1.5 $^3P_1$ 341.0 $^3P_0$ 489.9 $^1D_2$ 20873.4 $^1S_0$ 44918.1 *143*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 505777 ±5 $^2D^\circ_{2\frac{1}{2}}$ 34084 $^2D^\circ_{1\frac{1}{2}}$ 34120 $^2P^\circ_{1\frac{1}{2}}$, $^2P^\circ_{0\frac{1}{2}}$ } 51558 *135, 144*	$2p^2$ $^3P_0$ 702830 $^3P_1$ 225.2 $^3P_2$ 612.2 $^1D_2$ 25234.4 $^1S_0$ 53537 *17, 46, 135*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 921430 $^2P^\circ_{1\frac{1}{2}}$ 744.5 *46, 48*	$2s^2$ $^1S_0$ 1267622 49	$2s$ $^2S_{0\frac{1}{2}}$ 1493629 49	$1s^2$ $^1S_0$ 7693810 *145*	$1s$ $^2S_{0\frac{1}{2}}$ 8897240 68			
10	Ne	$2p^6$ $^1S_0$ 173929.70 *133*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 330391.0 $^2P^\circ_{0\frac{1}{2}}$ 780.45 *48, 146*	$2p^4$ $^3P_2$ 511800 $^3P_1$ 642.9 $^3P_0$ 920.4 $^1D_2$ 25840.8 $^1S_0$ 55750 *17, 46, 146*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 783300 $^2D^\circ_{2\frac{1}{2}}$ [41217] $^2D^\circ_{1\frac{1}{2}}$ 41262 $^2P^\circ_{0\frac{1}{2}}$ 62417 $^2P^\circ_{1\frac{1}{2}}$ 62423 *17, 46*	$2p^2$ $^3P_0$ 1018000 $^3P_1$ 414 $^3P_2$ 1112 $^1D_2$ 30293 $^1S_0$ 63899 *17, 46*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 1273800 $^2P^\circ_{1\frac{1}{2}}$ 1310 *14, 46, 48*	$2s^2$ $^1S_0$ 1671792 49	$2s$ $^2S_{0\frac{1}{2}}$ 1928462 *49*	$1s^2$ $^1S_0$ 9645005 *49, 145*	$1s$ $^2S_{0\frac{1}{2}}$ 10986876 *49, 68*		
11	Na	$3s$ $^2S_{0\frac{1}{2}}$ 41449.44 ±0.03 *162*	$2p^6$ $^1S_0$ 381395 ±1 *12*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 577800 $^2P^\circ_{0\frac{1}{2}}$ 1366 *46, 48*	$2p^4$ $^3P_2$ 797800 $^3P_1$ 1105.5 $^3P_0$ 1576 $^1D_2$ 30839.4 $^1S_0$ 66492 *17, 44, 46, 135*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 1116200 $^2D^\circ_{2\frac{1}{2}}$ 48337 $^2D^\circ_{1\frac{1}{2}}$ 48362 $^2P^\circ_{0\frac{1}{2}}$ 73221 $^2P^\circ_{1\frac{1}{2}}$ 73260 *44, 46, 135*	$2p^2$ $^3P_0$ 1388500 $^3P_1$ 698 $^3P_2$ 1858 $^1D_2$ [35518] $^1S_0$ [74434] *17, 46, 135*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 1681500 $^2P^\circ_{1\frac{1}{2}}$ 2139 *46, 48*	$2s^2$ $^1S_0$ 2130800 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 2418700 *46*	$1s^2$ $^1S_0$ 11817061 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 13297676 68	

387-063 O - 70 (Face p. 6) No. 1

TABLE 2. *Ionization limits and lowest terms*—continued

Z	Element	Spectrum I	II	III	IV	V	VI	VII	VIII
12	Mg	$3s^2$ $^1S_0$ 61671.02 ±0.02 *159*	$3s$ $^2S_{0\frac{1}{2}}$ 121267.61 ±0.05 *161*	$2p^6$ $^1S_0$ 646110 ±20 *5*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 881100 $^2P^\circ_{0\frac{1}{2}}$ 2227 *46, 48*	$2p^4$ $^3P_2$ 1139400 $^3P_1$ 1780 $^3P_0$ 2519 $^1D_2$ 35890 $^1S_0$ 77254 *44, 46, 135*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 1504300 $^2D^\circ_{2\frac{1}{2}}$ 55245 $^2D^\circ_{1\frac{1}{2}}$ 55266 $^2P^\circ_{0\frac{1}{2}}$ 83805 $^2P^\circ_{1\frac{1}{2}}$ 83927 *44, 46, 135*	$2p^2$ $^3P_0$ 1814300 $^3P_1$ 1127 $^3P_2$ 2939 $^1D_2$ [41003] $^1S_0$ [85191] *17, 46, 135*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 2144700 $^2P^\circ_{1\frac{1}{2}}$ 3302.2 *46, 48*
13	Al	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 48278.37 ±0.02 $^2P^\circ_{1\frac{1}{2}}$ 112.061 *56*	$3s^2$ $^1S_0$ 151860.4 ±0.5 *135*	$3s$ $^2S_{0\frac{1}{2}}$ 229445.71 ±0.2 *87*	$2p^6$ $^1S_0$ 967800 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 1239800 $^2P^\circ_{0\frac{1}{2}}$ 3442 *46, 48*	$2p^4$ $^3P_2$ 1536300 $^3P_1$ 2736 $^3P_0$ 3831 $^1D_2$ 41140 $^1S_0$ 88210 *44, 46, 135*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 1947300 $^2D^\circ_{1\frac{1}{2}}$ 62080 $^2D^\circ_{2\frac{1}{2}}$ 62140 $^2P^\circ_{0\frac{1}{2}}$ 94380 $^2P^\circ_{1\frac{1}{2}}$ 94650 *44, 46, 135*	$2p^2$ $^3P_0$ 2295400 $^3P_1$ 1740 $^3P_2$ 4440 *46, 135*
14	Si	$3p^2$ $^3P_0$ 65747.5 ±0.6 $^3P_1$ 77.115 $^3P_2$ 223.157 $^1D_2$ 6298.850 $^1S_0$ 15394.370 *150*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 131838.4 ±0.1 $^2P^\circ_{1\frac{1}{2}}$ 287.32 *172*	$3s^2$ $^1S_0$ 270139.3 ±0.4 *186*	$3s$ $^2S_{0\frac{1}{2}}$ 364093.1 ±0.6 *185*	$2p^6$ $^1S_0$ 1345100 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 1653900 $^2P^\circ_{0\frac{1}{2}}$ 5097 *46, 48*	$2p^4$ $^3P_2$ 1988400 $^3P_1$ 4030 $^3P_0$ 5570 $^1D_2$ 46550 $^1S_0$ 99330 *44, 46, 135*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 2445300 $^2D^\circ_{1\frac{1}{2}}$ 67140+x $^2D^\circ_{2\frac{1}{2}}$ 67420+x $^2P^\circ_{0\frac{1}{2}}$ 103320+x $^2P^\circ_{1\frac{1}{2}}$ 103900+x *46, 135*
15	P	$3p^3$ $^4S^\circ_{1\frac{1}{2}}$ 84580 $^2D^\circ_{1\frac{1}{2}}$ 11360.8 $^2D^\circ_{2\frac{1}{2}}$ 11376.4 $^2P^\circ_{0\frac{1}{2}}$ 18722.65 $^2P^\circ_{1\frac{1}{2}}$ 18747.95 *118*	$3p^2$ $^3P_0$ 159100 $^3P_1$ 164.8 $^3P_2$ 469.0 $^1D_2$ 8882.6 $^1S_0$ 21576.2 *118*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 243400 $^2P^\circ_{1\frac{1}{2}}$ 559.6 *47, 135*	$3s^2$ $^1S_0$ 414312.4 *135*	$3s$ $^2S_{0\frac{1}{2}}$ 524460 *45*	$2p^6$ $^1S_0$ 1777900 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 2123100 $^2P^\circ_{0\frac{1}{2}}$ 7268 *46, 48, 135*	$2p^4$ $^3P_2$ 2495600 $^3P_1$ 5757 $^3P_0$ 7826 $^1D_2$ 52450+x $^1S_0$ 110970+x *46, 135*
16	S	$3p^4$ $^3P_2$ 83558.0 $^3P_1$ 396.09 $^3P_0$ 573.65 $^1D_2$ 9238.58 $^1S_0$ 22179.99 *88, 98*	$3p^3$ $^4S^\circ_{1\frac{1}{2}}$ 188200 $^2D^\circ_{1\frac{1}{2}}$ 14853.0 $^2D^\circ_{2\frac{1}{2}}$ 14884.8 $^2P^\circ_{0\frac{1}{2}}$ 24524.9 $^2P^\circ_{1\frac{1}{2}}$ 24571.6 *17, 47*	$3p^2$ $^3P_0$ 280900 $^3P_1$ 297.2 $^3P_2$ 832.5 $^1D_2$ 11320.8 $^1S_0$ 27159.1 *17, 47, 135*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 381541.4 $^2P^\circ_{1\frac{1}{2}}$ 950.2 *135*	$3s^2$ $^1S_0$ [586200] *116*	$3s$ $^2S_{0\frac{1}{2}}$ 710184 *45*	$2p^6$ $^1S_0$ 2265900 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 2647400 $^2P^\circ_{0\frac{1}{2}}$ 10087 *46, 48*
17	Cl	$3p^5$ $^2P^\circ_{1\frac{1}{2}}$ 104591.0 ±0.3 $^2P^\circ_{0\frac{1}{2}}$ 882.36 *151*	$3p^4$ $^3P_2$ 192070 $^3P_1$ 696.1 $^3P_0$ 996.4 $^1D_2$ 11653.5 $^1S_0$ 27877.8 *17, 98*	$3p^3$ $^4S^\circ_{1\frac{1}{2}}$ 319500 $^2D^\circ_{1\frac{1}{2}}$ 18053.0 $^2D^\circ_{2\frac{1}{2}}$ 18118.6 $^2P^\circ_{0\frac{1}{2}}$ 29812.8 $^2P^\circ_{1\frac{1}{2}}$ 29905.6 *17, 47*	$3p^2$ $^3P_0$ 431226 $^3P_1$ 491 $^3P_2$ 1341 $^1D_2$ 13767 $^1S_0$ 32547 *17, 135*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 547000 $^2P^\circ_{1\frac{1}{2}}$ 1492 *135*	$3s^2$ $^1S_0$ [782600] *116*	$3s$ $^2S_{0\frac{1}{2}}$ 921051 *45*	$2p^6$ $^1S_0$ 2809100 *46*
18	Ar	$3p^6$ $^1S_0$ 127109.9 ±0.1 *135, 191*	$3p^5$ $^2P^\circ_{1\frac{1}{2}}$ 222848.2 $^2P^\circ_{0\frac{1}{2}}$ 1431.41 *130*	$3p^4$ $^3P_2$ 328600 $^3P_1$ 1112.1 $^3P_0$ 1570.2 $^1D_2$ 14010.0 $^1S_0$ 33265.7 *17, 47, 135*	$3p^3$ $^4S^\circ_{1\frac{1}{2}}$ 482400 $^2D^\circ_{1\frac{1}{2}}$ 21090.7 $^2D^\circ_{2\frac{1}{2}}$ 21219.5 $^2P^\circ_{0\frac{1}{2}}$ 34856.2 $^2P^\circ_{1\frac{1}{2}}$ 35033.1 *17, 135*	$3p^2$ $^3P_0$ 605100 $^3P_1$ 765 $^3P_2$ 2030 $^1D_2$ 16300 $^1S_0$ 37913 *17, 135*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 734040 $^2P^\circ_{1\frac{1}{2}}$ 2208 *52*	$3s^2$ $^1S_0$ 1002730 *52*	$3s$ $^2S_{0\frac{1}{2}}$ 1157080 *52*
19	K	$4s$ $^2S_{0\frac{1}{2}}$ 35009.77 ±0.02 *162*	$3p^6$ $^1S_0$ 255076 *134*	$3p^5$ $^2P^\circ_{1\frac{1}{2}}$ 368800 $^2P^\circ_{0\frac{1}{2}}$ 2166 *52, 182*	$3p^4$ $^3P_2$ 491300 $^3P_1$ 1673 $^3P_0$ 2325 $^1D_2$ 16384.0 $^1S_0$ 38546.2 *17, 135, 182*	$3p^3$ $^4S^\circ_{1\frac{1}{2}}$ [666700] $^2D^\circ_{1\frac{1}{2}}$ 24012.7 $^2D^\circ_{2\frac{1}{2}}$ 24249.5 $^2P^\circ_{0\frac{1}{2}}$ 39758 $^2P^\circ_{1\frac{1}{2}}$ 40077 *17, 116*	$3p^2$ $^3P_0$ [806600] $^3P_1$ 1132 $^3P_2$ 2924 $^1D_2$ 18978 *52, 116, 135*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 948200 $^2P^\circ_{1\frac{1}{2}}$ 3133 *52*	$3s^2$ $^1S_0$ 1249100 *52*
20	Ca	$4s^2$ $^1S_0$ 49305.72 *160*	$4s$ $^2S_{0\frac{1}{2}}$ 95751.87 ±0.03 *50*	$3p^6$ $^1S_0$ 410614.1 *16*	$3p^5$ $^2P^\circ_{1\frac{1}{2}}$ 541200 $^2P^\circ_{0\frac{1}{2}}$ 3118.0 *16, 52*	$3p^4$ $^3P_2$ 680800 $^3P_1$ 2406 $^3P_0$ 3276 $^1D_2$ 18830.1 *17, 135, 182*	$3p^3$ $^4S^\circ_{1\frac{1}{2}}$ [877400] $^2D^\circ_{1\frac{1}{2}}$ 26851 $^2D^\circ_{2\frac{1}{2}}$ 27267 *52, 116*	$3p^2$ $^3P_0$ 1030000 $^3P_1$ 1628 $^3P_2$ 4075 $^1D_2$ 21864 *52, 135*	$3p$ $^2P^\circ_{0\frac{1}{2}}$ 1187600 $^2P^\circ_{1\frac{1}{2}}$ 4304 *52*

Z	Element	Spectrum IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI
12	Mg	$2s^2$ $^1S_0$ 2645200 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 2964400 *46*	$1s^2$ $^1S_0$ 14210261 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 15829951 *49, 68*									
13	Al	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 2663400 $^2P^\circ_{1\frac{1}{2}}$ 4890 *46, 48*	$2s^2$ $^1S_0$ 3214800 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 3565600 *46*	$1s^2$ $^1S_0$ 16825022 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 18584138 *68*								
14	Si	$2p^2$ $^3P_0$ 2831900 $^3P_1$ 2590 $^3P_2$ 6460 *46, 135*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 3237800 $^2P^\circ_{1\frac{1}{2}}$ 6988.7 *46, 48*	$2s^2$ $^1S_0$ 3839800 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 4222400 *46*	$1s^2$ $^1S_0$ 19661693 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 21560630 *49, 68*							
15	P	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 2998300 $^2D^\circ_{1\frac{1}{2}}$ 73167 $^2D^\circ_{2\frac{1}{2}}$ 73730 $^2P^\circ_{0\frac{1}{2}}$ 113457 $^2P^\circ_{1\frac{1}{2}}$ 114430 *46, 135*	$2p^2$ $^3P_0$ 3423900 $^3P_1$ [3705] $^3P_2$ [9050] $^1D_2$ 59330 $^1S_0$ 119430 *42, 46, 135*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 3868100 $^2P^\circ_{1\frac{1}{2}}$ 9700 *46, 135*	$2s^2$ $^1S_0$ 4520100 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 4935000 *46*	$1s^2$ $^1S_0$ 22720766 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 24759942 *68*						
16	S	$2p^4$ $^3P_2$ 3057700 $^3P_1$ 7970 $^3P_0$ 10630 $^1D_2$ 58000+x $^1S_0$ 122300+x *46, 135*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 3606100 $^2D^\circ_{1\frac{1}{2}}$ 77670+x $^2D^\circ_{2\frac{1}{2}}$ 78800+x $^2P^\circ_{0\frac{1}{2}}$ [122230]+x $^2P^\circ_{1\frac{1}{2}}$ 124080+x *40, 46, 135*	$2p^2$ $^3P_0$ 4071400 $^3P_1$ 5200 $^3P_2$ 12400 *40, 46*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 4554300 $^2P^\circ_{1\frac{1}{2}}$ 13135.3 *46, 48*	$2s^2$ $^1S_0$ 5255900 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 5703600 *46*	$1s^2$ $^1S_0$ 26002663 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 28182535 *49, 68*					
17	Cl	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 3226700 $^2P^\circ_{0\frac{1}{2}}$ 13641 *46, 48*	$2p^4$ $^3P_2$ 3674900 $^3P_1$ 10880 $^3P_0$ 14140 $^1D_2$ 61000+x $^1S_0$ 130310+x *39, 46, 135*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 4268900 $^2D^\circ_{1\frac{1}{2}}$ 91960+x $^2D^\circ_{2\frac{1}{2}}$ [94000]+x $^2P^\circ_{0\frac{1}{2}}$ 141150+x $^2P^\circ_{1\frac{1}{2}}$ 144200+x *40, 46*	$2p^2$ $^3P_0$ 4774700 $^3P_1$ 7200 $^3P_2$ 16600 *40, 46*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 5296700 $^2P^\circ_{1\frac{1}{2}}$ *46*	$2s^2$ $^1S_0$ 6047200 *46*	$2s$ $^2S_{0\frac{1}{2}}$ 6528300 *46*	$1s^2$ $^1S_0$ 29507950 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 31829012 *49, 68*				
18	Ar	$2p^6$ $^1S_0$ 3407300 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 3860900 $^2P^\circ_{0\frac{1}{2}}$ 18067 *46, 48*	$2p^4$ $^3P_2$ 4347000 $^3P_1$ 14390 $^3P_0$ 18230 *39, 46*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 4986600 *40, 46*	$2p^2$ $^3P_0$ 5533800 $^3P_1$ 9900 $^3P_2$ 21900 *40, 46*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 6095500 $^2P^\circ_{1\frac{1}{2}}$ 22657 *42, 46, 48*	$2s^2$ $^1S_0$ 6894200 *46*	$2s$ $^2S_{0\frac{1}{2}}$ [7404400] *116*	$1s^2$ $^1S_0$ 33237173 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 35699936 *68*			
19	K	$3s$ $^2S_{0\frac{1}{2}}$ 1418070 *52*	$2p^6$ $^1S_0$ 4060600 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 4550100 $^2P^\circ_{0\frac{1}{2}}$ 23475 *46, 48*	$2p^4$ $^3P_2$ 5074100 $^3P_1$ 18970 $^3P_0$ 23250 *40, 46, 59*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 5759100 *46*	$2p^2$ $^3P_0$ 6348800 $^3P_1$ $^3P_2$ *46*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ 6950800 $^2P^\circ_{1\frac{1}{2}}$ *46*	$2s^2$ $^1S_0$ [7807600] *116*	$2s$ $^2S_{0\frac{1}{2}}$ [8340000] *116*	$1s^2$ $^1S_0$ 37190818 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 39795865 *49, 68*		
20	Ca	$3s^2$ $^1S_0$ 1520700 *52*	$3s$ $^2S_{0\frac{1}{2}}$ 1704050 *52*	$2p^6$ $^1S_0$ 4768900 *46*	$2p^5$ $^2P^\circ_{1\frac{1}{2}}$ 5294300 $^2P^\circ_{0\frac{1}{2}}$ 30044 *46, 48*	$2p^4$ $^3P_2$ 5856000 $^3P_1$ 24460 $^3P_0$ 28860 *46, 59, 89*	$2p^3$ $^4S^\circ_{1\frac{1}{2}}$ 6586600 *46*	$2p^2$ $^3P_0$ 7219800 $^3P_1$ 17558 $^3P_2$ 35922 *46, 89*	$2p$ $^2P^\circ_{0\frac{1}{2}}$ [7856000] $^2P^\circ_{1\frac{1}{2}}$ *116*	$2s^2$ $^1S_0$ [8767000] *116*	$2s$ $^2S_{0\frac{1}{2}}$ [9332000] *116*	$1s^2$ $^1S_0$ 41369608 *129*	$1s$ $^2S_{0\frac{1}{2}}$ 44117547 *49, 68*	

Z	Element	Spectrum I	II	III	IV	V	VI	VII
21	Sc	$3d\,4s^2$ $^2D_{1\frac12}$ 52750 $^2D_{2\frac12}$ 168.34 *27, 135*	$3d\,4s$ $^3D_1$ 103240 $^3D_2$ 67.68 $^3D_3$ 177.63 $^1D_2$ 2540.97 *135, 166*	$3d$ $^2D_{1\frac12}$ 199700 $^2D_{2\frac12}$ 197.5 *25, 135*	$3p^6$ $^1S_0$ 592600 *52*	$3p^5$ $^2P^o_{1\frac12}$ 739300 $^2P^o_{\frac12}$ 4318 *52, 182*	$3p^4$ $^3P_2$ 896000 $^3P_1$ 3348 $^3P_0$ 4458 $^1D_2$ 21398 *135, 182*	$3p^3$ $^4S^o_{1\frac12}$ [1113100] $^2D^o_{1\frac12}$ 29565 $^2D^o_{2\frac12}$ 30247 *52, 116*
22	Ti	$3d^2\,4s^2$ $^3F_2$ 55010 $^3F_3$ 170.132 $^3F_4$ 386.874 *27, 73*	$3d^2\,4s$ $^4F_{1\frac12}$ 109506 $^4F_{2\frac12}$ 93.94 $^4F_{3\frac12}$ 225.47 $^4F_{4\frac12}$ 393.22 *135, 166*	$3d^2$ $^3F_2$ 221735 $^3F_3$ 184.9 $^3F_4$ 420.4 $^1D_2$ 8473.5 $^3P_0$ 10538.4 $^3P_1$ 10603.6 $^3P_2$ 10721.2 *51*	$3d$ $^2D_{1\frac12}$ 348973 $^2D_{2\frac12}$ 382.1 *51*	$3p^6$ $^1S_0$ 800300 *52*	$3p^5$ $^2P^o_{1\frac12}$ 962700 $^2P^o_{\frac12}$ 5829 *52, 182*	$3p^4$ $^3P_2$ 1136000 $^3P_1$ 4530 $^3P_0$ 5884 $^1D_2$ 24130 *135, 182*
23	V	$3d^3\,4s^2$ $^4F_{1\frac12}$ 54400 $^4F_{2\frac12}$ 137.38 $^4F_{3\frac12}$ 323.42 $^4F_{4\frac12}$ 553.02 *27, 135*	$3d^4$ $^5D_0$ 118200 $^5D_1$ 36.05 $^5D_2$ 106.63 $^5D_3$ 208.89 $^5D_4$ 339.21 *135, 188*	$3d^3$ $^4F_{1\frac12}$ 236 $^4F_{2\frac12}$ 145.5 $^4F_{3\frac12}$ 341.5 $^4F_{4\frac12}$ 583.8 *83*	$3d^2$ $^3F_2$ 376730 ±40 $^3F_3$ 325.4 $^3F_4$ 734.7 $^1D_2$ 10959.3 *85*	$3d$ $^2D_{1\frac12}$ [526100] $^2D_{2\frac12}$ 620 *85, 116, 135*	$3p^6$ $^1S_0$ 1033400 *52*	$3p^5$ $^2P^o_{1\frac12}$ 1211200 $^2P^o_{\frac12}$ 7660 *52, 135*
24	Cr	$3d^5\,4s$ $^7S_3$ 54570 *103*	$3d^5$ $^6S_{2\frac12}$ 133060 *102*	$3d^4$ $^5D_0$ 249700 $^5D_1$ 59.9 $^5D_2$ 181.9 $^5D_3$ 355.8 $^5D_4$ 575.0 *136*	$3d^3$ $^4F_{1\frac12}$ [396000] $^4F_{2\frac12}$ 244 $^4F_{3\frac12}$ 561 $^4F_{4\frac12}$ 956 *116, 136*	$3d^2$ $^3F_2$ [559000] $^3F_3$ 513 $^3F_4$ 1146 $^1D_2$ 13200 *116, 136*	$3d$ $^2D_{1\frac12}$ 730400 $^2D_{2\frac12}$ 920 *3*	$3p^6$ $^1S_0$ 1299700 *136*
25	Mn	$3d^5\,4s^2$ $^6S_{2\frac12}$ 59970 *21*	$3d^5\,4s$ $^7S_3$ 126145.0 ±0.6 *86*	$3d^5$ $^6S_{2\frac12}$ 271550 *69*	$3d^4$ $^5D_0$ [413000] $^5D_1$ 98.4 $^5D_2$ 286.8 $^5D_3$ 552.7 $^5D_4$ 885.4 *116, 138*	$3d^3$ $^4F_{1\frac12}$ [584000] $^4F_{2\frac12}$ 349 $^4F_{3\frac12}$ 827 $^4F_{4\frac12}$ 1406 *116, 136*	$3d^2$ $^3F_2$ [766000] $^3F_3$ 746 $^3F_4$ 1669 $^1D_2$ 15337 *17, 116, 136*	$3d$ $^2D_{1\frac12}$ 962001 $^2D_{2\frac12}$ 1355 *136*
26	Fe	$3d^6\,4s^2$ $^5D_4$ 63480 $^5D_3$ 415.932 $^5D_2$ 704.003 $^5D_1$ 888.132 $^5D_0$ 978.076 *27, 43*	$3d^6\,4s$ $^6D_{4\frac12}$ 130524 $^6D_{3\frac12}$ 384.77 $^6D_{2\frac12}$ 667.64 $^6D_{1\frac12}$ 862.63 $^6D_{\frac12}$ 977.03 *136, 166*	$3d^6$ $^5D_4$ 247221 $^5D_3$ 436.2 $^5D_2$ 738.9 $^5D_1$ 932.4 $^5D_0$ 1027.3 *74, 136*	$3d^5$ $^6S_{2\frac12}$ [442000] *116*	$3d^4$ $^5D_0$ [604900] $^5D_1$ 145 $^5D_2$ 419 $^5D_3$ 804 $^5D_4$ 1285 *116, 136*	$3d^3$ $^4F_{1\frac12}$ [798500] $^4F_{2\frac12}$ 510.9 $^4F_{3\frac12}$ 1189 $^4F_{4\frac12}$ 2002 *17, 116*	$3d^2$ $^3F_2$ [1008000] $^3F_3$ 1051 $^3F_4$ 2327 *17, 116*
27	Co	$3d^7\,4s^2$ $^4F_{4\frac12}$ 63430 $^4F_{3\frac12}$ 816.00 $^4F_{2\frac12}$ 1406.84 $^4F_{1\frac12}$ 1809.33 *27, 136*	$3d^8$ $^3F_4$ 137572 $^3F_3$ 950.45 $^3F_2$ 1597.20 *166, 187*	$3d^7$ $^4F_{4\frac12}$ 270200 $^4F_{3\frac12}$ 841.2 $^4F_{2\frac12}$ 1451.3 $^4F_{1\frac12}$ 1866.8 *171*	$3d^6$ $^5D_4$ [413800] $^5D_3$ $^5D_2$ $^5D_1$ $^5D_0$ *116*	$3d^5$ $^6S_{2\frac12}$ [641200] *116*	$3d^4$ $^5D_0$ [823000] $^5D_1$ 208 $^5D_2$ 586 $^5D_3$ 1129 $^5D_4$ 1789 *116, 136*	$3d^3$ $^4F_{1\frac12}$ [1040000] $^4F_{2\frac12}$ 698 $^4F_{3\frac12}$ 1610 $^4F_{4\frac12}$ 2723 *116, 136*
28	Ni	$3d^8\,4s^2$ $^3F_4$ 61579 $^3F_3$ 1332.153 $^3F_2$ 2216.519 *136*	$3d^9$ $^2D_{2\frac12}$ 146541.56 $^2D_{1\frac12}$ 1506.94 *174*	$3d^8$ $^3F_4$ 283700 $^3F_3$ 1360.7 $^3F_2$ 2269.6 *27, 170*	$3d^7$ $^4F_{4\frac12}$ [442800] $^4F_{3\frac12}$ 1188.4 $^4F_{2\frac12}$ 2040.9 $^4F_{1\frac12}$ 2618.8 *116, 148*	$3d^6$ $^5D_4$ [609000] $^5D_3$ $^5D_2$ $^5D_1$ $^5D_0$ *116*	$3d^5$ $^6S_{2\frac12}$ [871000] *116*	$3d^4$ $^5D_0$ [1073000] $^5D_1$ 275 $^5D_2$ 802 $^5D_3$ 1520 $^5D_4$ 2379 *116, 136*
29	Cu	$4s$ $^2S_{\frac12}$ 62317.2 *136*	$3d^{10}$ $^1S_0$ 163669.2 ±0.5 *163*	$3d^9$ $^2D_{2\frac12}$ 297100 $^2D_{1\frac12}$ 2071.8 *136*	$3d^8$ $^3F_4$ 445124 ±1600 $^3F_3$ 1862.5 $^3F_2$ 3078.5 *169*	$3d^7$ $^4F_{4\frac12}$ [644500] $^4F_{3\frac12}$ $^4F_{2\frac12}$ $^4F_{1\frac12}$ *116*	$3d^6$ $^5D_4$ [831000] $^5D_3$ $^5D_2$ $^5D_1$ $^5D_0$ *116*	$3d^5$ $^6S_{2\frac12}$ [1121000] *116*

Z	Element	VIII	IX	X	XI	XII	XIII	XIV
21	Sc	$3p^2$ $^3P_0$ 1280000 $^3P_1$ 2272 $^3P_2$ 5505 $^1D_2$ 25035 *52, 60, 135*	$3p$ $^2P^o_{\frac12}$ 1452000 $^2P^o_{1\frac12}$ 5761 *52*	$3s^2$ $^1S_0$ 1817400 *52*	$3s$ $^2S_{\frac12}$ 2015080 *52*	$2p^6$ $^1S_0$ 5532200 *46*	$2p^5$ $^2P^o_{1\frac12}$ 6093400 $^2P^o_{\frac12}$ 37900 *46, 59*	$2p^4$ $^3P_2$ 6692900 $^3P_1$ $^3P_0$ *46*
22	Ti	$3p^3$ $^4S^o_{1\frac12}$ 1359000 $^2D^o_{1\frac12}$ 32168 $^2D^o_{2\frac12}$ 33239 *33, 52*	$3p^2$ $^3P_0$ [1558000] $^3P_1$ 3125 $^3P_2$ 7291 $^1D_2$ 28557 *52, 116, 183*	$3p$ $^2P^o_{\frac12}$ 1741500 $^2P^o_{1\frac12}$ 7542 *52*	$3s^2$ $^1S_0$ 2139300 *52*	$3s$ $^2S_{\frac12}$ 2351140 *52*	$2p^6$ $^1S_0$ 6350400 *46*	$2p^5$ $^2P^o_{1\frac12}$ 6947300 $^2P^o_{\frac12}$ 47190 *46, 59*
23	V	$3p^4$ $^3P_2$ 1401000 $^3P_1$ 6000 $^3P_0$ 7580 $^1D_2$ 27120 *135*	$3p^3$ $^4S^o_{1\frac12}$ [1659900] *116*	$3p^2$ $^3P_0$ [1859200] $^3P_1$ 4310 $^3P_2$ 9540 *60, 116*	$3p$ $^2P^o_{\frac12}$ 2057100 $^2P^o_{1\frac12}$ 9692 *52*	$3s^2$ $^1S_0$ 2486300 *52*	$3s$ $^2S_{\frac12}$ 2712250 *52*	$2p^6$ $^1S_0$ 7223500 *46*
24	Cr	$3p^5$ $^2P^o_{1\frac12}$ [1490000] $^2P^o_{\frac12}$ 9900 *116, 136*	$3p^4$ $^3P_2$ [1688000] $^3P_1$ 7860 $^3P_0$ 9600 *116, 136*	$3p^3$ $^4S^o_{1\frac12}$ [1971000] *116*	$3p^2$ $^3P_0$ [2184000] $^3P_1$ $^3P_2$ *116*	$3p$ $^2P^o_{\frac12}$ [2403600] $^2P^o_{1\frac12}$ 12200 *60, 116*	$3s^2$ $^1S_0$ 2862000 *136*	$3s$ $^2S_{\frac12}$ 3099630 *136*
25	Mn	$3p^6$ $^1S_0$ [1584600] *116*	$3p^5$ $^2P^o_{1\frac12}$ [1789000] $^2P^o_{\frac12}$ 12530 *116, 136*	$3p^4$ $^3P_2$ [2003000] $^3P_1$ 10000 $^3P_0$ 11700 *116, 136*	$3p^3$ $^4S^o_{1\frac12}$ [2307000] *116*	$3p^2$ $^3P_0$ [2535900] $^3P_1$ $^3P_2$ *116*	$3p$ $^2P^o_{\frac12}$ [2771400] $^2P^o_{1\frac12}$ 16400 *62, 116*	$3s^2$ $^1S_0$ 3260000 *136*
26	Fe	$3d$ $^2D_{1\frac12}$ 1218400 $^2D_{2\frac12}$ 1850 *3, 32, 34*	$3p^6$ $^1S_0$ 1895800 *3*	$3p^5$ $^2P^o_{1\frac12}$ 2114000 $^2P^o_{\frac12}$ 15682.9 *89, 136*	$3p^4$ $^3P_2$ 2342000 $^3P_1$ 12667.9 $^3P_0$ 14440 *89, 136*	$3p^3$ $^4S^o_{1\frac12}$ [2668000] *116*	$3p^2$ $^3P_0$ [2912000] $^3P_1$ 9302.6 $^3P_2$ 18561.1 *89, 116*	$3p$ $^2P^o_{\frac12}$ [3163000] $^2P^o_{1\frac12}$ 18850.6 *89, 116*
27	Co	$3d^2$ $^3F_2$ [1266000] $^3F_3$ 1430 $^3F_4$ 3140 *4, 116*	$3d$ $^2D_{1\frac12}$ 1501300 $^2D_{2\frac12}$ 2440 *3, 75*	$3p^6$ $^1S_0$ 2230000 *3*	$3p^5$ $^2P^o_{1\frac12}$ 2462000 $^2P^o_{\frac12}$ 19420 *75, 136*	$3p^4$ $^3P_2$ [2710000] $^3P_1$ $^3P_0$ *116*	$3p^3$ $^4S^o_{1\frac12}$ [3057000] *116*	$3p^2$ $^3P_0$ [3315000] $^3P_1$ [11834] $^3P_2$ *116, 136*
28	Ni	$3d^3$ $^4F_{1\frac12}$ [1307000] $^4F_{2\frac12}$ $^4F_{3\frac12}$ $^4F_{4\frac12}$ *116*	$3d^2$ $^3F_2$ [1557000] $^3F_3$ 1890 $^3F_4$ 4110 *58, 116*	$3d$ $^2D_{1\frac12}$ 1811000 $^2D_{2\frac12}$ 3150 *3, 67*	$3p^6$ $^1S_0$ 2591000 *3*	$3p^5$ $^2P^o_{1\frac12}$ [2839000] $^2P^o_{\frac12}$ 23627.3 *89, 116*	$3p^4$ $^3P_2$ [3097000] $^3P_1$ 19541.8 $^3P_0$ [20200] *89, 116, 136*	$3p^3$ $^4S^o_{1\frac12}$ [3468000] *116*
29	Cu	$3d^4$ $^5D_0$ [1339000] $^5D_1$ $^5D_2$ $^5D_3$ $^5D_4$ *116*	$3d^3$ $^4F_{1\frac12}$ [1605000] $^4F_{2\frac12}$ $^4F_{3\frac12}$ $^4F_{4\frac12}$ *116*	$3d^2$ $^3F_2$ [1871000] $^3F_3$ 2485 $^3F_4$ 5465 *58, 116*	$3d$ $^2D_{1\frac12}$ 2146000 $^2D_{2\frac12}$ *3*	$3p^6$ $^1S_0$ [2975000] *116*	$3p^5$ $^2P^o_{1\frac12}$ [3234000] $^2P^o_{\frac12}$ *116*	$3p^4$ $^3P_2$ [3509000] $^3P_1$ $^3P_0$ *116*

Z	Element	XV	XVI	XVII	XVIII	XIX	XX	XXI
21	Sc	$2p^3$ $^4S^o_{1\frac12}$ 7468900 *46*						
22	Ti	$2p^4$ $^3P_2$ 7584700 $^3P_1$ $^3P_0$ *46*						
23	V	$2p^5$ $^2P^o_{1\frac12}$ 7856200 $^2P^o_{\frac12}$ *30, 46*						
24	Cr	$2p^6$ $^1S_0$ 8151600 *46*						
25	Mn	$3s$ $^2S_{\frac12}$ 3511210 *136*	$2p^6$ $^1S_0$ 9164300 *136*					
26	Fe	$3s^2$ $^1S_0$ 3684000 *136*	$3s$ $^2S_{\frac12}$ 3947840 *136*	$2p^6$ $^1S_0$ 10211700 *136*				
27	Co	$3p$ $^2P^o_{\frac12}$ [3581000] $^2P^o_{1\frac12}$ *116*	$3s^2$ $^1S_0$ 4133000 *136*	$3s$ $^2S_{\frac12}$ 4410480 *136*	$2p^6$ $^1S_0$ 11316400 *136*			
28	Ni	$3p^2$ $^3P_0$ [3742500] $^3P_1$ 14917.5 $^3P_2$ 27376.5 *89, 116*	$3p$ $^2P^o_{\frac12}$ [4025000] $^2P^o_{1\frac12}$ 27761.4 *89, 116*	$3s^2$ $^1S_0$ [4606000] *116*	$3s$ $^2S_{\frac12}$ 4897400 *136*	$2p^6$ $^1S_0$ 12477000 *63*		
29	Cu	$3p^3$ $^4S^o_{1\frac12}$ [3904000] *116*	$3p^2$ $^3P_0$ [4194000] $^3P_1$ $^3P_2$ *116*	$3p$ $^2P^o_{\frac12}$ [4493000] $^2P^o_{1\frac12}$ *116*	$3s^2$ $^1S_0$ [5106000] *116*	$3s$ $^2S_{\frac12}$ 5410000 *136*	$2p^6$ $^1S_0$ 13695000 *63*	

297-063 O - 70 (Face p. 6) No. 7

TABLE 2. *Ionization limits and lowest terms*—continued

Z	Element	Spectrum I	II	III	IV	V
30	Zn	$4s^2$ $^1S_0$ 75768.10 *95*	$4s$ $^2S_{1/2}$ 144892.6 ±2 *122*	$3d^{10}$ $^1S_0$ 320390 ±1 *41*	$3d^9$ $^2D_{5/2}$ [479100] $^2D_{3/2}$ 2758.8 *37, 116*	$3d^8$ $^3F_4$ [666000] $^3F_3$ $^3F_2$ *116*
31	Ga	$4p$ $^2P^\circ_{1/2}$ 48387.63 $^2P^\circ_{3/2}$ 826.19 *96*	$4s^2$ $^1S_0$ 165458 *136*	$4s$ $^2S_{1/2}$ 247700 *136*	$3d^{10}$ $^1S_0$ 517600 *136*	
32	Ge	$4p^2$ $^3P_0$ 63715 ±10 $^3P_1$ 557.1341 $^3P_2$ 1409.9609 $^1D_2$ 7125.2989 $^1S_0$ 16367.3332 *6, 97*	$4p$ $^2P^\circ_{1/2}$ 128521.3 ±0.2 $^2P^\circ_{3/2}$ 1767.356 *97, 100*	$4s^2$ $^1S_0$ 276036 *136*	$4s$ $^2S_{1/2}$ 368701 *136*	$3d^{10}$ $^1S_0$ 753800 *136*
33	As	$4p^3$ $^4S^\circ_{3/2}$ 79165 *136*	$4p^2$ $^3P_0$ 150290 $^3P_1$ 1061 $^3P_2$ 2538 $^1D_2$ 10097 $^1S_0$ 22602 *35*	$4p$ $^2P^\circ_{1/2}$ 228670 $^2P^\circ_{3/2}$ 2940 *35, 136*	$4s^2$ $^1S_0$ 404369 *136*	$4s$ $^2S_{1/2}$ 505136 *136*
34	Se	$4p^4$ $^3P_2$ 78658.22 $^3P_1$ 1989.49 $^3P_0$ 2534.35 $^1D_2$ 9576.08 $^1S_0$ 22446.03 *136*	$4p^3$ $^4S^\circ_{3/2}$ 170900 *26*	$4p^2$ $^3P_0$ 248583 $^3P_1$ 1741 $^3P_2$ 3937 $^1D_2$ 13032 *36, 136*	$4p$ $^2P^\circ_{1/2}$ 346375 $^2P^\circ_{3/2}$ 4376 *36, 136*	$4s^2$ $^1S_0$ [551000] *65*
35	Br	$4p^5$ $^2P^\circ_{3/2}$ 95284.8 ±0.5 $^2P^\circ_{1/2}$ 3685.24 *184*	$4p^4$ $^3P_2$ 175870 $^3P_1$ 3136.4 $^3P_0$ 3837.5 $^1D_2$ 12089.1 $^1S_0$ 27867.1 *152, 184*	$4p^3$ $^4S^\circ_{3/2}$ 289529 *136*	$4p^2$ $^3P_0$ [381600] $^3P_1$ 3247 $^3P_2$ 6237 $^1D_2$ 18115 *65, 136*	$4p$ $^2P^\circ_{1/2}$ [481600] $^2P^\circ_{3/2}$ 6090 *65, 136*
36	Kr	$4p^6$ $^1S_0$ 112914.5 *136, 147*	$4p^5$ $^2P^\circ_{3/2}$ 196474.8 $^2P^\circ_{1/2}$ 5371.00 *132, 136*	$4p^4$ $^3P_2$ 298020 $^3P_1$ 4548 $^3P_0$ 5313 $^1D_2$ 14644 $^1S_0$ 33079 *136*	$4p^3$ $^4S^\circ_{3/2}$ [423600] *65*	$4p^2$ $^3P_0$ [522000] $^3P_1$ $^3P_2$ *65*
37	Rb	$5s$ $^2S_{1/2}$ 33690.81 ±0.01 *91*	$4p^6$ $^1S_0$ 220048 ±30 *155a*	$4p^5$ $^2P^\circ_{3/2}$ 320000 $^2P^\circ_{1/2}$ 7380 *136*	$4p^4$ $^3P_2$ [424400[$^3P_1$ $^3P_0$ *65*	$4p^3$ $^4S^\circ_{3/2}$ [572800] *65*
38	Sr	$5s^2$ $^1S_0$ 45932.0 ±0.2 *70*	$5s$ $^2S_{1/2}$ 88964.0 *136*	$4p^6$ $^1S_0$ [351800] *65*	$4p^5$ $^2P^\circ_{3/2}$ 460000 $^2P^\circ_{1/2}$ 9731 *136*	$4p^4$ $^3P_2$ [577700] $^3P_1$ $^3P_0$ *65*
39	Y	$4d\ 5s^2$ $^2D_{3/2}$ 51447 $^2D_{5/2}$ 530.36 *22, 136*	$5s^2$ $^1S_0$ 98690 *22*	$5s$ $^2S_{1/2}$ 165500 *24, 104*	$4p^6$ $^1S_0$ [498600] *65*	$4p^5$ $^2P^\circ_{3/2}$ [621200] $^2P^\circ_{1/2}$ 12459.9 *65, 155*
40	Zr	$4d^2\ 5s^2$ $^3F_2$ 55145 $^3F_3$ 570.41 $^3F_4$ 1240.84 *22, 136*	$4d^2\ 5s$ $^4F_{3/2}$ 105900 $^4F_{5/2}$ 314.67 $^4F_{7/2}$ 763.44 $^4F_{9/2}$ 1322.91 *23, 136*	$4d^2$ $^3F_2$ 185400 $^3F_3$ 680.5 $^3F_4$ 1485.7 *24, 104*	$4d$ $^2D_{3/2}$ 276970 $^2D_{5/2}$ 1250 *104*	$4p^6$ $^1S_0$ 657600 *28*

Z	Element	VI	VII	VIII	IX	X	XI	XII
30	Zn	$3d^7$ $^4F_{9/2}$ [871000] $^4F_{7/2}$ $^4F_{5/2}$ $^4F_{3/2}$ *116*	$3d^6$ $^5D_4$ [1081000] $^5D_3$ $^5D_2$ $^5D_1$ $^5D_0$ *116*	$3d^5$ $^6S_{5/2}$ [1403000] *116*	$3d^4$ $^5D_0$ [1637000] $^5D_1$ $^5D_2$ $^5D_3$ $^5D_4$ *116*	$3d^3$ $^4F_{3/2}$ [1920000] $^4F_{5/2}$ $^4F_{7/2}$ $^4F_{9/2}$ *116*	$3d^2$ $^3F_2$ [2210000] $^3F_3$ 3030 $^3F_4$ 6735 *58, 116*	$3d$ $^2D_{3/2}$ [2507000] $^2D_{5/2}$ *116*
31	Ga							
32	Ge							
33	As	$3d^{10}$ $^1S_0$ 1028800 *136*						
34	Se	$4s$ $^2S_{1/2}$ 658994 *136*	$3d^{10}$ $^1S_0$ 1253300 *136*					
35	Br	$4s^2$ $^1S_0$ [714800] *65*	$4s$ $^2S_{1/2}$ [831000] *65*	$3d^{10}$ $^1S_0$ 1554700 *136*				
36	Kr	$4p$ $^2P^\circ_{1/2}$ [633300] $^2P^\circ_{3/2}$ 8108 *61, 65*	$4s^2$ $^1S_0$ [895500[*65*	$4s$ $^2S_{1/2}$ [1016500] *65*	$3d^{10}$ $^1S_0$ 1862400 *106*			
37	Rb	$4p^2$ $^3P_0$ [680900] $^3P_1$ $^3P_2$ *65*	$4p$ $^2P^\circ_{1/2}$ [800300[$^2P^\circ_{3/2}$ *65*	$4s^2$ $^1S_0$ [1098000] *65*	$4s$ $^2S_{1/2}$ [1210000] *65*	$3d^{10}$ $^1S_0$ 2235100 *136*		
38	Sr	$4p^3$ $^4S^\circ_{3/2}$ [732600] *65*	$4p^2$ $^3P_0$ [855200] $^3P_1$ $^3P_2$ *65*	$4p$ $^2P^\circ_{1/2}$ [986700] $^2P^\circ_{3/2}$ *65*	$4s^2$ $^1S_0$ [1307000] *65*	$4s$ $^2S_{1/2}$ [1428000] *65*	$3d^{10}$ $^1S_0$ 2613800 *136*	
39	Y	$4p^4$ $^3P_2$ [750300] $^3P_1$ $^3P_0$ *65*	$4p^3$ $^4S^\circ_{3/2}$ [935900[*65*	$4p^2$ $^3P_0$ [1041000] $^3P_1$ $^3P_2$ *65*	$4p$ $^2P^\circ_{1/2}$ [1179500] $^2P^\circ_{3/2}$ *65*	$4s^2$ $^1S_0$ [1541000] *65*	$4s$ $^2S_{1/2}$ [1662000] *65*	$3d^{10}$ $^1S_0$ 3016800 *136*
40	Zr							

Z	Element	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI
30	Zn	$3p^6$ $^1S_0$ [3385000] *116*	$3p^5$ $^2P^\circ_{3/2}$ [3662000] $^2P^\circ_{1/2}$ *116*	$3p^4$ $^3P_2$ [3952000] $^3P_1$ $^3P_0$ *116*	$3p^3$ $^4S^\circ_{3/2}$ [4372000] *116*	$3p^2$ $^3P_0$ [4670000] $^3P_1$ $^3P_2$ *116*	$3p$ $^2P^\circ_{1/2}$ [4993000] $^2P^\circ_{3/2}$ *116*	$3s^2$ $^1S_0$ [5630000] *116*	$3s$ $^2S_{1/2}$ 5952000 *64*	$2p^6$ $^1S_0$ 14969000 *63*

TABLE 2. *Ionization limits and lowest terms* — continued

Z	Element	Spectrum I	II	III	IV	V	VI	VII	VIII	IX
41	Nb	$4d^4\ 5s$ $^6D^o_{1/2}$ 55511 $^6D^o_{3/2}$ 154.19 $^6D^o_{5/2}$ 391.99 $^6D^o_{7/2}$ 695.25 $^6D^o_{9/2}$ 1050.26 *22*	$4d^4$ $^5D_0$ 115500 $^5D_1$ 158.99 $^5D_2$ 438.38 $^5D_3$ 801.38 $^5D_4$ 1224.87 *23, 136*	$4d^3$ $^4F_{3/2}$ 202000 $^4F_{5/2}$ 515.8 $^4F_{7/2}$ 1176.6 $^4F_{9/2}$ 1939.0 *24, 82*	$4d^2$ $^3F_2$ 308600 $^3F_3$ 1086.4 $^3F_4$ 2344.6 *136*	$4d$ $^2D_{3/2}$ 407700 $^2D_{5/2}$ 1870 *104, 136*	$4p^6$ $^1S_0$ 827300 *28*	$4p^5$ $^2P^o_{3/2}$ 1005000 $^2P^o_{1/2}$ 19199 *28, 136*		
42	Mo	$4d^5\ 5s$ $^7S_3$ 57260 *137*	$4d^5$ $^6S_{5/2}$ 130300 *137*	$4d^4$ $^5D_0$ 219100 $^5D_1$ 243.10 $^5D_2$ 669.60 $^5D_3$ 1225.20 $^5D_4$ 1873.80 *158*	$4d^3$ $^4F_{3/2}$ 374180 $^4F_{5/2}$ 780.0 $^4F_{7/2}$ 1759.0 $^4F_{9/2}$ 2858.6 *137*	$4d^2$ $^3F_2$ 493360 $^3F_3$ 1585 $^3F_4$ 3359 *137*	$4d$ $^2D_{3/2}$ 549000 $^2D_{5/2}$ 2578 *104, 137*	$4p^6$ $^1S_0$ 1022800 *28*	$4p^5$ $^2P^o_{3/2}$ 1235000 $^2P^o_{1/2}$ 23273 *28, 137*	
43	Tc	$4d^5\ 5s^2$ $^6S_{5/2}$ 58700 *137*	$4d^5\ 5s$ $^7S_3$ 123100 *137*	$4d^5$ $^6S_{5/2}$ 238300 *24*						
44	Ru	$4d^7\ 5s$ $^5F_5$ 59410 $^5F_4$ 1190.64 $^5F_3$ 2091.54 $^5F_2$ 2713.24 $^5F_1$ 3105.49 *101*	$4d^7$ $^4F_{9/2}$ 135200 $^4F_{7/2}$ 1523.1 $^4F_{5/2}$ 2493.9 $^4F_{3/2}$ 3104.2 *175*	$4d^6$ $^5D_4$ 229600 $^5D_3$ 1158.8 $^5D_2$ 1826.3 $^5D_1$ 2266.3 $^5D_0$ 2476.0 *137*						
45	Rh	$4d^8\ 5s$ $^4F_{9/2}$ 60197 $^4F_{7/2}$ 1529.97 $^4F_{5/2}$ 2598.03 $^4F_{3/2}$ 3472.68 *137*	$4d^8$ $^3F_4$ 145800 $^3F_3$ 2401.3 $^3F_2$ 3580.7 *137*	$4d^7$ $^4F_{9/2}$ 250500 $^4F_{7/2}$ 2147.8 $^4F_{5/2}$ 3485.7 $^4F_{3/2}$ 4322.0 *84, 137*						
46	Pd	$4d^{10}$ $^1S_0$ 67236.0 *137*	$4d^9$ $^2D_{5/2}$ 156700 $^2D_{3/2}$ 3539 *137*	$4d^8$ $^3F_4$ 265600 $^3F_3$ 3229.3 $^3F_2$ 4687.5 *173*						
47	Ag	$5s$ $^2S_{1/2}$ 61106.50 *137*	$4d^{10}$ $^1S_0$ 173300 *137*	$4d^9$ $^2D_{5/2}$ 280900 $^2D_{3/2}$ 4607 *137*						
48	Cd	$5s^2$ $^1S_0$ 72538.8 *137*	$5s$ $^2S_{1/2}$ 136374.74 *137*	$4d^{10}$ $^1S_0$ 302300 *137*						
49	In	$5s^2\ 5p$ $^2P^o_{1/2}$ 46670.11 ±0.05 $^2P^o_{3/2}$ 2212.598 *96*	$5s^2$ $^1S_0$ 152195 *137*	$5s$ $^2S_{1/2}$ 226100 *137*	$4d^{10}$ $^1S_0$ 439000 *137*					
50	Sn	$5p^2$ $^3P_0$ 59231.8 $^3P_1$ 1691.8 $^3P_2$ 3427.7 *137*	$5s^2\ 5p$ $^2P^o_{1/2}$ 118017.0 $^2P^o_{3/2}$ 4251.4 *137*	$5s^2$ $^1S_0$ 246020.0 *137*	$5s$ $^2S_{1/2}$ 328550.0 *137*	$4d^{10}$ $^1S_0$ 583000 *137*				
51	Sb	$5p^3$ $^4S^o_{3/2}$ 69700 *137*	$5p^2$ $^3P_0$ 133327.5 $^3P_1$ 3055.0 $^3P_2$ 5659.0 *137*	$5s^2\ 5p$ $^2P^o_{1/2}$ 204248 $^2P^o_{3/2}$ 6576 *137*	$5s^2$ $^1S_0$ 356156 *137*	$5s$ $^2S_{1/2}$ 449300 *137*	$4d^{10}$ $^1S_0$ 868000 *137*			
52	Te	$5p^4$ $^3P_2$ 72667 $^3P_1$ 4751 $^3P_0$ 4707 *137*	$5p^3$ $^4S^o_{3/2}$ 150000 ±3000 *79*	$5p^2$ $^3P_0$ 225500 $^3P_1$ 4756.5 $^3P_2$ 8166.9 *38*	$5s^2\ 5p$ $^2P^o_{1/2}$ 301776 $^2P^o_{3/2}$ 9222.6 *38*	$5s^2$ $^1S_0$ 473900 *38*	$5s$ $^2S_{1/2}$ 570000 *38*	$4d^{10}$ $^1S_0$ 1107000 *137*		
53	I	$5p^5$ $^2P^o_{3/2}$ 84295.1 ±0.2 $^2P^o_{1/2}$ 7603.15 *131*	$5p^4$ $^3P_2$ 154304 ±1 $^3P_1$ 7087.0 $^3P_0$ 6447.9 *121*	$5p^3$ $^4S^o_{3/2}$ [266000] *65*						

Z	Element	Spectrum I	II	III	IV	V	VI
54	Xe	$5p^6$ $^1S_0$ 97834.0 *137, 147*	$5p^5$ $^2P^\circ_{1\frac{1}{2}}$ 171068.4 $^2P^\circ_{0\frac{1}{2}}$ 10537.01 *137*	$5p^4$ $^3P_2$ 259089 $^3P_1$ 9794.6 $^3P_0$ 8131 *137*			
55	Cs	$6s$ $^2S_{0\frac{1}{2}}$ 31406.432 ±0.010 *11*	$5p^6$ $^1S_0$ 202263 *137*				
56	Ba	$6s^2$ $^1S_0$ 42035.14 ±0.05 *71*	$6s$ $^2S_{0\frac{1}{2}}$ 80686.87 *137*				
57	La	$5d\ 6s^2$ $^2D_{1\frac{1}{2}}$ 44981 ±5 $^2D_{2\frac{1}{2}}$ 1053.20 *72, 137*	$5d^2\ 6s^2$ $^3F_2$ 89200 ±650 $^3F_3$ 1016.10 $^3F_4$ 1970.70 *181*	$5d\ 6s^2$ $^2D_{1\frac{1}{2}}$ 154664 ±15 $^2D_{2\frac{1}{2}}$ 1603.26 *139*			
58	Ce	$4f\ 5d\ 6s^2$ $^1G^\circ_4$ 44090 ±110 *120, 156a*	$4f\ 5d^2$ $^4H^\circ_{3\frac{1}{2}}$ 87500 ±650 $^4H^\circ_{4\frac{1}{2}}$ 987.62 $^4H^\circ_{5\frac{1}{2}}$ 1873.95 $^4H^\circ_{6\frac{1}{2}}$ 2382.26 *80, 149, 181*	$4f^2$ $^3H_4$ 162900 ±120 $^3H_5$ 1526.36 $^3H_6$ 3127.05 *178*	$4f$ $^2F^\circ_{2\frac{1}{2}}$ 296200 $^2F^\circ_{3\frac{1}{2}}$ 2253 *113*		
59	Pr	$4f^3\ 6s^2$ $^4I^\circ_{4\frac{1}{2}}$ 43730 ±150 $^4I^\circ_{5\frac{1}{2}}$ 1376.54 $^4I^\circ_{6\frac{1}{2}}$ 2846.61 $^4I^\circ_{7\frac{1}{2}}$ *156, 193*	$4f^3\ 6s$ $^5I^\circ_4$ 85100 ±650 $^3I^\circ_5$ 441.94 $^5I^\circ_6$ 1649.01 $^5I^\circ_7$ 2998.31 $^3I^\circ_6$ 4437.09 *181*	$4f^3$ $^4I^\circ_{4\frac{1}{2}}$ 174420 ±130 $^4I^\circ_{5\frac{1}{2}}$ 1398.34 $^4I^\circ_{6\frac{1}{2}}$ 2893.14 $^4I^\circ_{7\frac{1}{2}}$ 4453.76 *177, 180*	$4f^2$ $^3H_4$ 314200 ±100 $^3H_5$ 2152.2 $^3H_6$ 4389.1 *179*	$4f$ $^2F^\circ_{2\frac{1}{2}}$ 463400 ±400 $^2F^\circ_{3\frac{1}{2}}$ 3027.4 *99*	
60	Nd	$4f^4\ 6s^2$ $^5I_4$ 44270 ±150 $^5I_5$ 1128.055 $^5I_6$ 2366.595 $^5I_7$ 3681.690 $^5I_8$ 5048.605 *156, 190*	$4f^4\ 6s$ $^6I_{3\frac{1}{2}}$ 86500 ±650 $^6I_{4\frac{1}{2}}$ 513.330 $^6I_{5\frac{1}{2}}$ 1470.100 $^6I_{6\frac{1}{2}}$ 2585.460 $^6I_{7\frac{1}{2}}$ 3801.935 $^6I_{8\frac{1}{2}}$ 5085.650 *181, 190*				
61	Pm	$4f^5\ 6s^2$ $^6H^\circ_{2\frac{1}{2}}$ 44800 ±150 $^6H^\circ_{3\frac{1}{2}}$ 803.82 $^6H^\circ_{4\frac{1}{2}}$ 1748.78 $^6H^\circ_{5\frac{1}{2}}$ 2797.10 $^6H^\circ_{6\frac{1}{2}}$ 3919.03 $^6H^\circ_{7\frac{1}{2}}$ 5089.79 *154, 156*	$4f^5\ 6s$ $^7H^\circ_2$ 87900 ±650 $^7H^\circ_3$ 446.45 $^7H^\circ_4$ 1133.45 $^7H^\circ_5$ 1983.52 $^7H^\circ_6$ 2950.31 $^7H^\circ_7$ $^7H^\circ_8$ *153, 181*				
62	Sm	$4f^6\ 6s^2$ $^7F_0$ 45420 ±150 $^7F_1$ 292.58 $^7F_2$ 811.92 $^7F_3$ 1489.55 $^7F_4$ 2273.09 $^7F_5$ 3125.46 $^7F_6$ 4020.66 *2, 156*	$4f^6\ 6s$ $^8F_{0\frac{1}{2}}$ 89300 ±650 $^8F_{1\frac{1}{2}}$ 326.64 $^8F_{2\frac{1}{2}}$ 838.22 $^8F_{3\frac{1}{2}}$ 1489.16 $^8F_{4\frac{1}{2}}$ 2237.97 $^8F_{5\frac{1}{2}}$ 3052.65 $^8F_{6\frac{1}{2}}$ 3909.62 *1, 181*				
63	Eu	$4f^7\ 6s^2$ $^8S^\circ_{3\frac{1}{2}}$ 45740 ±80 *168*	$4f^7\ 6s$ $^9S^\circ_4$ 90700 *167, 181*				

TABLE 2. *Ionization limits and lowest terms*—continued

Z	Element	Spectrum													
		I			II			III			IV			V	VI
64	Gd	$4f^7\ 5d\ 6s^2$	$^9D^{\circ}_{2}$	49530	$4f^7\ 5d\ 6s$	$^{10}D^{\circ}_{2\frac{1}{2}}$	97900								
				±110			±3000								
			$^9D^{\circ}_{3}$	215.13		$^{10}D^{\circ}_{3\frac{1}{2}}$	261.81								
			$^9D^{\circ}_{4}$	532.98		$^{10}D^{\circ}_{4\frac{1}{2}}$	633.27								
			$^9D^{\circ}_{5}$	999.11		$^{10}D^{\circ}_{5\frac{1}{2}}$	1158.94								
			$^9D^{\circ}_{6}$	1719.06		$^{10}D^{\circ}_{6\frac{1}{2}}$	1935.30								
		156a, 165			*165, 181*										
65	Tb	$4f^9\ 6s^2$	$^6H^{\circ}_{7\frac{1}{2}}$	[47200]	$4f^9\ 6s$	$^7H_8$	92900								
				±150			±650								
			$^6H^{\circ}_{6\frac{1}{2}}$			$^7H_7$									
			$^6H^{\circ}_{5\frac{1}{2}}$			$^7H_6$									
			$^6H^{\circ}_{4\frac{1}{2}}$			$^7H_5$									
			$^6H^{\circ}_{3\frac{1}{2}}$			$^7H_4$									
			$^6H^{\circ}_{2\frac{1}{2}}$			$^7H_3$									
		156, 176				$^7H_2$									
					181										
66	Dy	$4f^{10}\ 6s^2$	$^5I_8$	47820	$4f^{10}\ 6s$	$^6I_{8\frac{1}{2}}$	94100								
				±150			±650								
			$^5I_7$	4134.24		$^6I_{7\frac{1}{2}}$	4341.10								
			$^5I_6$	7050.61		$^6I_{6\frac{1}{2}}$	7485.09								
			$^5I_5$			$^6I_{5\frac{1}{2}}$	7463.88								
			$^5I_4$			$^6I_{4\frac{1}{2}}$	9432.07								
		31, 156				$^6I_{3\frac{1}{2}}$	10953.94								
					31, 181										
67	Ho	$4f^{11}\ 6s^2$	$^4I^{\circ}_{7\frac{1}{2}}$	48540	$4f^{11}\ 6s$	$^5I^{\circ}_8$	95200								
				±150			±650								
			$^4I^{\circ}_{6\frac{1}{2}}$			$^5I^{\circ}_7$									
			$^4I^{\circ}_{5\frac{1}{2}}$			$^5I^{\circ}_6$									
			$^4I^{\circ}_{4\frac{1}{2}}$			$^5I^{\circ}_5$									
		156				$^5I^{\circ}_4$									
					181										
68	Er	$4f^{12}\ 6s^2$	$^3H_6$	49210	$4f^{12}\ 6s$	$^4H_{6\frac{1}{2}}$	96200								
				±150			±650								
			$^3H_5$	6958.34		$^4H_{5\frac{1}{2}}$	7149.7								
			$^3H_4$	10750.99		$^4H_{4\frac{1}{2}}$	11042.8								
		117, 156				$^4H_{3\frac{1}{2}}$	10894.1								
					125, 181										
69	Tm	$4f^{13}\ 6s^2$	$^2F^{\circ}_{3\frac{1}{2}}$	49840	$4f^{13}\ 6s$	$^3F^{\circ}_4$	97200	$4f^{13}$	$^2F^{\circ}_{3\frac{1}{2}}$	191200					
				±150			±650			±500					
			$^2F^{\circ}_{2\frac{1}{2}}$	8771.25		$^3F^{\circ}_3$	236.94		$^2F^{\circ}_{2\frac{1}{2}}$	8774.02					
		126, 156				$^3F^{\circ}_2$	8769.69	*180a*							
					126, 181										
70	Yb	$4f^{14}\ 6s^2$	$^1S_0$	50441.0	$4f^{14}\ 6s$	$^2S_{\frac{1}{2}}$	98150	$4f^{14}$	$^1S_0$	203300					
				±0.2	*128*			*20*							
		20a													
71	Lu	$5d\ 6s^2$	$^2D_{1\frac{1}{2}}$	43762.39	$6s^2$	$^1S_0$	112000								
				±0.10			±3000								
			$^2D_{2\frac{1}{2}}$	1993.92	*181*										
		20b, 110													
72	Hf	$5d^2\ 6s^2$	$^3F_2$	56600	$5d\ 6s^2$	$^2D_{1\frac{1}{2}}$	120000	$5d^2$	$^3F_2$	187800	$5d$	$^2D_{1\frac{1}{2}}$	268500		
			$^3F_3$	2356.68		$^2D_{2\frac{1}{2}}$	3050.88		$^3F_3$	3288.7			±800		
			$^3F_4$	4567.64	*137*				$^3F_4$	6095.1		$^2D_{2\frac{1}{2}}$	4692.0		
		127						*111*			*111*				
73	Ta	$5d^3\ 6s^2$	$^4F_{1\frac{1}{2}}$	63600											
			$^4F_{2\frac{1}{2}}$	2010.10											
			$^4F_{3\frac{1}{2}}$	3963.92											
			$^4F_{4\frac{1}{2}}$	5621.04											
		137													

387-003 O - 70 (Face p. 6) No. 4

TABLE 2. *Ionization limits and lowest terms*—continued

Z	Element	Spectrum I	II	III	IV	V	VI
74	W	$5d^4\ 6s^2$ ${}^5D_0$ 64400 ${}^5D_1$ 1670.29 ${}^5D_2$ 3325.53 ${}^5D_3$ 4830.00 ${}^5D_4$ 6219.33 *114, 137*					
75	Re	$5d^5\ 6s^2$ ${}^6S_{2\frac{1}{2}}$ 63530 *137*					
76	Os	$5d^6\ 6s^2$ ${}^5D_4$ 70450 ${}^5D_3$ 4159.32 ${}^5D_2$ 2740.49 ${}^5D_1$ 5766.14 ${}^5D_0$ 6092.79 *108, 137*					
77	Ir	$5d^7\ 6s^2$ ${}^4F_{4\frac{1}{2}}$ 73000 ±800 ${}^4F_{3\frac{1}{2}}$ 6323.96 ${}^4F_{2\frac{1}{2}}$ 5784.63 ${}^4F_{1\frac{1}{2}}$ 4078.95 *107*					
78	Pt	$5d^9\ 6s$ ${}^3D_3$ 72300 ${}^3D_2$ 775.9 ${}^3D_1$ 10132.0 *137*	$5d^9$ ${}^2D_{2\frac{1}{2}}$ 149723 ${}^2D_{1\frac{1}{2}}$ 8419.9 *137*				
79	Au	$5d^{10}\ 6s$ ${}^2S_{0\frac{1}{2}}$ 74410.0 *137*	$5d^{10}$ ${}^1S_0$ 165000 *137*				
80	Hg	$6s^2$ ${}^1S_0$ 84184.1 *137*	$5d^{10}\ 6s$ ${}^2S_{0\frac{1}{2}}$ 151280 *137*	$5d^{10}$ ${}^1S_0$ 276000 *137*			
81	Tl	$6s^2\ 6p$ ${}^2P^\circ_{0\frac{1}{2}}$ 49266.7 ±0.1 ${}^2P^\circ_{1\frac{1}{2}}$ 7792.7 *157*	$6s^2$ ${}^1S_0$ 164765 ±5 *137*	$6s$ ${}^2S_{0\frac{1}{2}}$ 240600 *137*			
82	Pb	$6p^2$ ${}^3P_0$ 59819.4 ±0.3 ${}^3P_1$ 7819.2626 ${}^3P_2$ 10650.3271 *189*	$6s^2\ 6p$ ${}^2P^\circ_{0\frac{1}{2}}$ 121243 ±3 ${}^2P^\circ_{1\frac{1}{2}}$ 14081.074 *137, 189*	$6s^2$ ${}^1S_0$ 257592 ±5 *137*	$6s$ ${}^2S_{0\frac{1}{2}}$ 341350 *137*	$5d^{10}$ ${}^1S_0$ 555000 *137*	
83	Bi	$6p^3$ ${}^4S^\circ_{1\frac{1}{2}}$ 58790 *137*	$6p^2$ ${}^3P_0$ 134600 ${}^3P_1$ 13324 ${}^3P_2$ 17030 *137*	$6s^2\ 6p$ ${}^2P^\circ_{0\frac{1}{2}}$ 206180 ${}^2P^\circ_{1\frac{1}{2}}$ 20788 *137*	$6s^2$ ${}^1S_0$ 365500 *137*	$6s$ ${}^2S_{0\frac{1}{2}}$ 451700 *137*	$5d^{10}$ ${}^1S_0$ 712000 *137*
84	Po	$6p^4$ ${}^3P_2$ 67885.3 ${}^3P_1$ 16831.61 ${}^3P_0$ 7514.69 *29*					
85	At						
86	Rn	$6p^6$ ${}^1S_0$ 86692.5 *137*					
87	Fr						
88	Ra	$7s^2$ ${}^1S_0$ 42577.35 *137*	$7s$ ${}^2S_{0\frac{1}{2}}$ 81842.31 *137*				
89	Ac	$6d\ 7s^2$ ${}^2D_{1\frac{1}{2}}$ [55600] ${}^2D_{2\frac{1}{2}}$ 2231.43 *65, 137*	$7s^2$ ${}^1S_0$ 97300 *137*				

Table 2. *Ionization limits and lowest terms*—Continued

Z	Element	Spectrum					
		I	II	III	IV	V	VI
90	Th	$6d^2\ 7s^2$ $^3F_2$ $^3F_3$ 2869.260 $^3F_4$ 4961.661 *192*	$6d^2\ 7s$ $^4F_{1\frac{1}{2}}$ [93000] $^4F_{2\frac{1}{2}}$ 1521.91 $^4F_{3\frac{1}{2}}$ 4146.57 $^4F_{4\frac{1}{2}}$ 6213.55 *65, 124*	$6d^2$ $^3F_2$ 161000 $^3F_3$ 3992.7 $^3F_4$ 6474.9 *109*	$5f$ $^2F^\circ_{2\frac{1}{2}}$ 231900 $^2F^\circ_{3\frac{1}{2}}$ 4325.38 *112*		
91	Pa						
92	U						
93	Np						
94	Pu	$5f^6\ 7s^2$ $^7F_0$ 47000 $^7F_1$ 2203.55 $^7F_2$ 4299.55 $^7F_3$ 6144.34 $^7F_4$ 7774.45 $^7F_5$ 9179.05 $^7F_6$ 10238.24 *7, 8*					
95	Am	$5f^7\ 7s^2$ $^8S^\circ_{3\frac{1}{2}}$ 48770 *66*					

387-063 O - 70 (Face p. 6) No. 5

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